

SUPPLEMENTAL AMENDMENT

Serial Number: 09/945512

Filing Date: August 30, 2001

Title: IN SERVICE PROGRAMMABLE LOGIC ARRAYS WITH LOW TUNNEL BARRIER INTERPOLY INSULATORS

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IN THE CLAIMS

Please amend the claims as follows:

1. (Previously Amended) An in-service programmable logic array, comprising:
a first logic plane that receives a number of input signals, the first logic plane having a plurality of logic cells arranged in rows and columns that are interconnected to provide a number of logical outputs;

a second logic plane having a number of logic cells arranged in rows and columns that receive the outputs of the first logic plane and that are interconnected to produce a number of logical outputs such that the in service programmable logic array implements a logical function;
and

wherein each of the logic cells includes a floating gate transistor, comprising:

a first source/drain region and a second source/drain region separated by a channel region in a substrate;

a floating gate opposing the channel region and separated therefrom by a gate oxide;

a control gate opposing the floating gate and including a polysilicon layer and a metal layer; and

wherein the control gate is separated from the floating gate by a low tunnel barrier intergate insulator, the low tunnel barrier intergate insulator contacts the metal layer of the control gate and the floating gate.

2. (Previously Withdrawn)

3. (Original) The in-service programmable logic array of claim 1, wherein the low tunnel barrier intergate insulator includes a transition metal oxide.

4. (Original) The in-service programmable logic array of claim 3, wherein the transition metal oxide is selected from the group consisting of Ta₂O₅, TiO₂, ZrO₂, and Nb₂O₅.

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[5. (Previously Withdrawn)]

6. (Previously Amended) The in-service programmable logic array of claim 4, wherein the floating gate includes a polysilicon floating gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator.

7. (Previously Amended) An in-service programmable logic array, comprising:
a first logic plane that receives a number of input signals, the first logic plane having a plurality of logic cells arranged in rows and columns that are interconnected to provide a number of logical outputs;

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a second logic plane having a number of logic cells arranged in rows and columns that receive the outputs of the first logic plane and that are interconnected to produce a number of logical outputs such that the in service programmable logic array implements a logical function;
and

wherein each of the logic cells includes a floating gate transistor, comprising:

a first source/drain region and a second source/drain region separated by a channel region in a substrate;

a floating gate opposing the channel region and separated therefrom by a gate oxide;

a control gate opposing the floating gate;

wherein the control gate is separated from the floating gate by a low tunnel barrier intergate insulator;

wherein the floating gate includes a polysilicon floating gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator;

wherein the control gate includes a polysilicon control gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator.

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8. (Original) The in service programmable logic array of claim 1, wherein the first logic plane and the second logic plane each comprise NOR planes.
9. (Previously Amended) A programmable logic array, comprising:
a plurality of input lines for receiving an input signal;
a plurality of output lines; and
one or more arrays having a first logic plane and a second logic plane connected between the input lines and the output lines, wherein the first logic plane and the second logic plane comprise a plurality of logic cells arranged in rows and columns for providing a sum-of-products term on the output lines responsive to a received input signal, wherein each logic cell includes a vertical non-volatile memory cell including:
a first source/drain region formed on a substrate;
a body region including a channel region formed on the first source/drain region;
a second source/drain region formed on the body region;
a floating gate opposing the channel region and separated therefrom by a gate oxide;
a control gate opposing the floating gate;
wherein the control gate is separated from the floating gate by a low tunnel barrier intergate insulator; and
wherein the control gate includes a polysilicon control gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator.

10. (Previously Withdrawn)

11. (Previously Amended) The programmable logic array of claim 9, wherein the floating gate includes a polysilicon floating gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator; and wherein the metal layer of the floating gate is continuous.

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12. (Previously Amended) A programmable logic array, comprising:
a plurality of input lines for receiving an input signal;
a plurality of output lines; and
one or more arrays having a first logic plane and a second logic plane connected between the input lines and the output lines, wherein the first logic plane and the second logic plane comprise a plurality of logic cells arranged in rows and columns for providing a sum-of-products term on the output lines responsive to a received input signal, wherein each logic cell includes a vertical non-volatile memory cell including:

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- a first source/drain region formed on a substrate;
- a body region including a channel region formed on the first source/drain region;
- a second source/drain region formed on the body region;
- a floating gate opposing the channel region and separated therefrom by a gate oxide;
- a control gate opposing the floating gate;

wherein the control gate is separated from the floating gate by a low tunnel barrier intergate insulator;
wherein the floating gate includes a polysilicon floating gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator; and
wherein the control gate includes a polysilicon control gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator.

13. (Original) The programmable logic array of claim 9, wherein the floating gate includes a vertical floating gate formed alongside of the body region.

14. (Original) The programmable logic array of claim 13, wherein the control gate includes a vertical control gate formed alongside of the vertical floating gate.

15. - 27. (Previously Withdrawn)

1-17 28. (Previously Amended) A programmable logic array, comprising:
a plurality of input lines for receiving an input signal;

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a plurality of output lines; and

one or more arrays having a first logic plane and a second logic plane connected between the input lines and the output lines, wherein the first logic plane and the second logic plane comprise a plurality of logic cells arranged in rows and columns for providing a sum-of-products term on the output lines responsive to the received input signal, wherein each logic cell includes a vertical non-volatile memory cell including:

a number of pillars extending outwardly from a substrate, wherein each pillar includes a first source/drain region, a body region, and a second source/drain region;

a number of floating gates opposing the body regions in the number of pillars and separated therefrom by a gate oxide;

a number of control gates opposing the floating gates;

a plurality of buried source lines formed of single crystalline semiconductor material and disposed below the pillars in the array for interconnecting with the first source/drain region of pillars in the array;

wherein each of the number of input lines is disposed between rows of the pillars and integrally formed with the number of control gates and opposing the floating gates of the vertical non-volatile memory cells for serving as a control gate and are separated from the number of floating gates by a low tunnel barrier intergate insulator; and

wherein the control gate includes a polysilicon control gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator.

29. (Previously Withdrawn)

19 30. (Previously Amended) The programmable logic array of claim 28, wherein the floating gate includes a polysilicon floating gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator; and wherein the metal layer of the floating gate is continuous.

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20/31 (Previously Amended) A programmable logic array, comprising:
a plurality of input lines for receiving an input signal;
a plurality of output lines; and
one or more arrays having a first logic plane and a second logic plane connected between the input lines and the output lines, wherein the first logic plane and the second logic plane comprise a plurality of logic cells arranged in rows and columns for providing a sum-of-products term on the output lines responsive to the received input signal, wherein each logic cell includes a vertical non-volatile memory cell including:

a number of pillars extending outwardly from a substrate, wherein each pillar includes a first source/drain region, a body region, and a second source/drain region;

a number of floating gates opposing the body regions in the number of pillars and separated therefrom by a gate oxide;

a number of control gates opposing the floating gates;

a plurality of buried source lines formed of single crystalline semiconductor material and disposed below the pillars in the array for interconnecting with the first source/drain region of pillars in the array;

wherein each of the number of input lines is disposed between rows of the pillars and integrally formed with the number of control gates and opposing the floating gates of the vertical non-volatile memory cells for serving as a control gate and are separated from the number of floating gates by a low tunnel barrier integrate insulator; and

wherein the control gate includes a polysilicon control gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator.

21/32 (Original) The programmable logic array of claim 28, wherein the number of floating gates includes vertical floating gates formed alongside of the body region.

22/33 (Original) The programmable logic array of claim 32, wherein the number of control gates includes vertical control gates formed alongside of the vertical floating gates.

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34. (Previously Withdrawn)

24 35. (Original) The programmable logic array of claim 28, wherein the number of buried source lines are formed integrally with the first source/drain regions and are separated from the substrate by an oxide layer.

25 36. (Previously Amended) A low voltage programmable logic array, comprising:
a number of input lines for receiving an input signal;
a number of output lines; and

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a first logic plane that receives a number of input signals on the number of input lines, the first logic plane having a number of logic cells arranged in rows and columns that are interconnected to provide a number of logical outputs;

a second logic plane coupled to the first logic plane by a number of interconnect lines, the second logic plane having a number of logic cells arranged in rows and columns that receive the outputs of the first logic plane on the interconnect lines and that are interconnected to produce a number of logical outputs on the output lines such that the programmable logic array implements a logical function;

wherein each logic cell includes a vertical non-volatile memory cell including:

a number of pillars extending outwardly from a substrate, wherein each pillar includes a first source/drain region, a body region, and a second source/drain region;

a number of floating gates opposing the body regions in the number of pillars and separated therefrom by a gate oxide;

a number of control gates opposing the floating gates, wherein the number of control gates are separated from the number of floating gates by a low tunnel barrier integrate insulator, wherein the control gate includes a polysilicon control gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator;

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a number of buried source lines formed of single crystalline semiconductor material and disposed below the pillars in the array for interconnecting with the first source/drain regions of column adjacent pillars in the array.

26 ~~37~~ (Original) The low voltage programmable logic array of claim ~~36~~²⁵, wherein the number of input lines are disposed in a trench between rows of the pillars in the first logic plane and oppose the floating gates of the vertical non-volatile memory cells for serving as control gates, and wherein the number of interconnect lines couple to the second source/drain region in columns of pillars for implementing a logic function in the first logic plane.

DI cont 27 ~~38~~ (Original) The low voltage programmable logic array of claim ~~36~~²⁵, wherein the number of interconnect lines are disposed in a trench between rows of the pillars in the second logic plane and oppose the floating gates of the vertical non-volatile memory cells for serving as control gates, and wherein the number of output lines couple to the second source/drain region in columns of pillars for implementing a logic function in the second logic plane.

28 ~~39~~ (Original) The low voltage programmable logic array of claim ~~36~~²⁵, wherein column adjacent pillars are separated by a trench and each trench includes a pair of floating gates opposing the body regions on opposite sides of the trench.

29 ~~40~~ (Original) The low voltage programmable logic array of claim ~~39~~²⁸, wherein each trench in the first logic plane includes a single vertically oriented input line formed between the pair of floating gates for serving as a shared control gate.

30 ~~41~~ (Original) The low voltage programmable logic array of claim ~~39~~²⁸, wherein each trench in the second logic plane includes a single vertically oriented interconnect line formed between the pair of floating gates for serving as a shared control gate in the second logic plane.

31 ~~42~~ (Original) The low voltage programmable logic array of claim ~~39~~²⁸, wherein each trench in the first logic plane includes a pair of vertically oriented input lines formed between the pair

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of floating gates, and wherein each one of the pair of vertically oriented input lines independently addresses the floating gates on opposing sides of the trench, and wherein the pair of vertically oriented input lines are separated by an insulator layer.

32 43. (Original) The low voltage programmable logic array of claim 39, wherein the number of input lines are disposed vertically above the floating gates, and wherein each pair of floating gates shares a single input line in the first logic plane.

33 44. (Original) The low voltage programmable logic array of claim 39, wherein the number of input lines are disposed vertically above the floating gates, and wherein each one of the pair of floating gates is addressed by an independent one of the number of input lines in the first logic plane.

34 45. (Original) The low voltage programmable logic array of claim 39, wherein a pair of input lines are formed above the pair of floating gates in each trench in the first logic plane for serving as control lines, and wherein the interconnect lines are coupled to the second source/drain regions in the first logic plane and are formed above the pair of floating gates in each trench in the second logic plane for serving as control lines.

[46. - 47. (Previously Withdrawn)]

37 48. (Previously Amended) An electronic system, comprising:
a memory;
a processor coupled to the memory; and
wherein the processor includes at least one in service programmable logic array including:
a first logic plane that receives a number of input signals, the first logic plane having a plurality of logic cells arranged in rows and columns that are interconnected to provide a number of logical outputs;

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a second logic plane having a number of logic cells arranged in rows and columns that receive the outputs of the first logic plane and that are interconnected to produce a number of logical outputs such that the programmable logic array implements a logical function; and

wherein each of the logic cells includes a non-volatile memory cell including;

a first source/drain region and a second source/drain region separated by a channel region in a substrate;

a floating gate opposing the channel region and separated therefrom by a gate oxide;

a control gate opposing the floating gate;

wherein the control gate is separated from the floating gate by a low tunnel barrier intergate insulator; and

wherein the control gate includes a polysilicon control gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator.

49. (Previously Withdrawn)

39 50. (Original) The electronic system of claim 37, wherein the low tunnel barrier intergate insulator includes a transition metal oxide.

40 51. (Original) The electronic system of claim 50, wherein the transition metal oxide is selected from the group consisting of Ta₂O₅, TiO₂, ZrO₂, and Nb₂O₅.

41 52. (Previously Amended) The electronic system of claim 37, wherein the floating gate includes a polysilicon floating gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator; and wherein the metal layer of the floating gate is continuous.

42 53. (Previously Amended) An electronic system, comprising:
a memory;
a processor coupled to the memory; and

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wherein the processor includes at least one in service programmable logic array including:

- a first logic plane that receives a number of input signals, the first logic plane having a plurality of logic cells arranged in rows and columns that are interconnected to provide a number of logical outputs;
- a second logic plane having a number of logic cells arranged in rows and columns that receive the outputs of the first logic plane and that are interconnected to produce a number of logical outputs such that the programmable logic array implements a logical function; and

wherein each of the logic cells includes a non-volatile memory cell including;

- a first source/drain region and a second source/drain region separated by a channel region in a substrate;
- a floating gate opposing the channel region and separated therefrom by a gate oxide;
- a control gate opposing the floating gate, wherein the control gate is separated from the floating gate by a low tunnel barrier intergate insulator; and

wherein the floating gate includes a polysilicon floating gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator; and

wherein the control gate includes a polysilicon control gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator.

4/3/03 37 (Original) The electronic system of claim 48, wherein the first logic plane and the second logic plane each comprise NOR planes.

4/4/03 55 (Previously Amended) An electronic system, comprising:

- a memory;
- a processor coupled to the memory; and
- wherein at least one of the processor and memory include an in-service programmable logic array including:

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a number of input lines for receiving an input signal;

a number of output lines;

a first logic plane that receives a number of input signals on the number of input lines, the first logic plane having a number of logic cells arranged in rows and columns that are interconnected to provide a number of logical outputs;

a second logic plane coupled to the first logic plane by a number of interconnect lines, the second logic plane having a number of logic cells arranged in rows and columns that receive the outputs of the first logic plane on the interconnect lines and that are interconnected to produce a number of logical outputs on the output lines such that the programmable logic array implements a logical function;

wherein each logic cell includes a vertical non-volatile memory cell including:

a vertical pillar extending outwardly from a semiconductor substrate at intersections of the input lines and interconnect lines and at the intersections of the interconnect lines and the output lines, wherein each pillar includes a first source/drain region, a body region, and a second source/drain region;

a number of floating gates opposing the body regions in the number of pillars and separated therefrom by a gate oxide;

a number of control gates opposing the floating gates, wherein the number of control gates are separated from the number of floating gates by a low tunnel barrier integrate insulator, wherein the number of control gates includes a polysilicon control gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator;

a number of buried source lines formed of single crystalline semiconductor material and disposed below the pillars in the array for interconnecting with the first source/drain regions of column adjacent pillars in the array.

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45 56. (Original) The electronic system of claim 55, wherein the low tunnel barrier intergate insulator includes a metal oxide insulator selected from the group consisting of PbO, Al₂O₃, Ta₂O₅, TiO₂, ZrO₂, and Nb₂O₅.

46 57. (Previously Amended) The electronic system of claim 55, wherein each floating gate includes a polysilicon floating gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator; and wherein the metal layer of the floating gate is continuous.

47 58. (Previously Amended) An electronic system, comprising:

- a memory;
- a processor coupled to the memory; and
- wherein at least one of the processor and memory include an in-service programmable logic array including:
 - a number of input lines for receiving an input signal;
 - a number of output lines;
 - a first logic plane that receives a number of input signals on the number of input lines, the first logic plane having a number of logic cells arranged in rows and columns that are interconnected to provide a number of logical outputs;
 - a second logic plane coupled to the first logic plane by a number of interconnect lines, the second logic plane having a number of logic cells arranged in rows and columns that receive the outputs of the first logic plane on the interconnect lines and that are interconnected to produce a number of logical outputs on the output lines such that the programmable logic array implements a logical function;
 - wherein each logic cell includes a vertical non-volatile memory cell including:
 - a vertical pillar extending outwardly from a semiconductor substrate at intersections of the input lines and interconnect lines and at the intersections of the interconnect lines and the output lines, wherein each pillar includes a first source/drain region, a body region, and a second source/drain region;

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a number of floating gates opposing the body regions in the number of pillars and separated therefrom by a gate oxide;

a number of control gates opposing the floating gates, wherein the number of control gates are separated from the number of floating gates by a low tunnel barrier intergate insulator;

a number of buried source lines formed of single crystalline semiconductor material and disposed below the pillars in the array for interconnecting with the first source/drain regions of column adjacent pillars in the array;

wherein each floating gate includes a polysilicon floating gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator; and

wherein each control gate includes a polysilicon control gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator.

48.50. (Original) The electronic system of claim 55, wherein each floating gate is a vertical floating gate formed in a trench below a top surface of each pillar such that each trench houses a pair of floating gates opposing the body regions in adjacent pillars on opposing sides of the trench.

49.50. (Original) The electronic system of claim 59, wherein the number of control gates are formed in the trench below the top surface of the pillar and between the pair of floating gates, wherein each pair of floating gates shares a single control gate, and wherein each floating gate includes a vertically oriented floating gate having a vertical length of less than 100 nanometers.

50.51. (Original) The electronic system of claim 59, wherein the number of control gates are formed in the trench below the top surface of the pillar and between the pair of floating gates such that each trench houses a pair of control gate lines each addressing the floating gates one on opposing sides of the trench respectively, and wherein the pair of control gate lines are separated by an insulator layer.

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51 ⁴⁸ 62. (Original) The electronic system of claim 59, wherein the number of control gates are disposed vertically above the floating gates, and wherein each pair of floating gates shares a single control gate.

52 ⁴⁸ 63. (Original) The electronic system of claim 59, wherein the number of control gates are disposed vertically above the floating gates, and wherein each one of the pair of floating gates is addressed by an independent one of the number of control gates.

53 ⁴⁴ 64. (Original) The electronic system of claim 55, wherein each floating gate is a horizontally oriented floating gate formed in a trench below a top surface of each pillar such that each trench houses a floating gate opposing the body regions in adjacent pillars on opposing sides of the trench, and wherein each horizontally oriented floating gate has a vertical length of less than 100 nanometers opposing the body region of the pillars.

54 ⁵³ 65. (Original) The electronic system of claim 64, wherein the number of control gates are disposed vertically above the floating gates.

[66. - 94. (Previously Canceled)]

55 ⁵³ 95. (Previously Added) A programmable logic array, comprising:

- a plurality of input lines for receiving an input signal;
- a plurality of output lines; and
- one or more arrays having a first logic plane and a second logic plane connected between the input lines and the output lines, wherein the first logic plane and the second logic plane comprise a plurality of logic cells arranged in rows and columns for providing a sum-of-products term on the output lines responsive to the received input signal, wherein each logic cell includes a vertical non-volatile memory cell including:
 - a number of pillars extending outwardly from a substrate, wherein each pillar includes a first source/drain region, a body region, and a second source/drain region;

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a number of floating gates opposing the body regions in the number of pillars and separated therefrom by a gate oxide;

a number of control gates opposing the floating gates;

a plurality of buried source lines formed of single crystalline semiconductor material and disposed below the pillars in the array for interconnecting with the first source/drain region of pillars in the array;

wherein each of the number of input lines is disposed between rows of the pillars and integrally formed with the number of control gates and opposing the floating gates of the vertical non-volatile memory cells for serving as a control gate and are separated from the number of floating gates by a low tunnel barrier intergate insulator;

wherein the control gate includes a polysilicon control gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator; and

wherein the floating gate includes a polysilicon floating gate having a metal layer formed thereon in contact with the low tunnel barrier intergate insulator.

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56/96. (Previously Added) A programmable logic array, comprising:

a first logic plane including a first plurality of logic cells;

a second logic plane operably connected to the first plane and including a second plurality of logic cells; and

wherein at least one of the first plurality of logic cells and the second plurality of logic cells includes:

a first source/drain region and a second source/drain region separated by a channel region in a substrate;

a floating gate opposing the channel region and separated therefrom by a gate oxide, the floating gate including a first polysilicon layer and a first metal layer;

a control gate opposing the floating gate, the control gate including a second polysilicon layer and a second metal layer;

a low tunnel barrier intergate insulator in contact with both the first metal layer and the second metal layer.

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57 97. (Previously Added) The programmable logic array of claim 96, wherein the low tunnel barrier intergate insulator includes a metal oxide insulator selected from the group consisting of lead oxide (PbO) and aluminum oxide (Al₂O₃).

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58 98. (Previously Added) The programmable logic array of claim 96, wherein the low tunnel barrier intergate insulator includes a transition metal oxide.

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59 99. (Previously Added) The programmable logic array of claim 98, wherein the transition metal oxide is selected from the group consisting of Ta₂O₅, TiO₂, ZrO₂, and Nb₂O₅.

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60 100. (Previously Added) The programmable logic array of claim 96, wherein the low tunnel barrier intergate insulator includes a Perovskite oxide tunnel barrier.

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101. (Currently Amended) A programmable logic array, comprising:

a first logic plane including a first plurality of logic cells;

a second logic plane operably connected to the first plane and including a second plurality of logic cells; and

wherein at least one of the first plurality of logic cells and the second plurality of logic cells includes:

a first source/drain region and a second source/drain region separated by a channel region in a substrate;

a floating gate opposing the channel region and separated therefrom by a gate oxide, the floating gate including a first polysilicon layer and a continuous metal layer;

a control gate opposing the floating gate, the control gate including a metal layer; and

a low tunnel barrier intergate insulator in contact with the continuous metal layer of the floating gate and in contact with the metal layer of the control gate.

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62 102. (Currently Amended) The programmable logic array of claim 101, wherein the control gate further includes a second polysilicon layer ~~and a second metal layer, the second metal layer being separated from the continuous metal layer of the floating gate by the low tunnel barrier intergate insulator.~~

63 103. (Currently Amended) A programmable logic array, comprising:
a first logic plane including a first plurality of logic cells;
a second logic plane operably connected to the first plane and including a second plurality of logic cells; and
wherein at least one of the first plurality of logic cells and the second plurality of logic cells includes:

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- a first source/drain region and a second source/drain region separated by a channel region in a substrate;
 - a floating gate opposing the channel region and separated therefrom by a gate oxide, the floating gate including a first polysilicon layer and a first metal layer, the first metal layer having a uniform tunneling characteristic;
 - a control gate opposing the floating gate, the control gate including a second metal layer; and
 - a low tunnel barrier intergate insulator ~~in contact with~~ contacting and separating the first metal layer of the floating gate and the second metal layer of the control gate.

64 104. (Currently Amended) The programmable logic array of claim 103, wherein the control gate further includes a second polysilicon layer ~~and a second metal layer.~~

65 105. (Canceled) The programmable logic array of claim 104, wherein the low tunnel barrier intergate insulator contacts and separates the first metal layer and the second metal layer.